CENTRO EURO-MEDITERRANEO PER I CAMBIAMENTI CLIMATICI

ISTITUTO NAZIONALE di GEOFISICA e VULCANOLOGIA

Tropical Cyclones - Ocean feedbacks: Effects on the Ocean Heat Transport as simulated by a High Resolution Coupled General Circulation Model

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2) CMCC - Euro Mediterranean Center for Climate Change - Bologna, Italy
3) MPI – Max Plank Institute for Meteorology – Hamburg, Germany

Asia Oceania Geosciences Society 2011 - AS09-OS07 Taipei, 8-12 August 2011

OUTLINE

1. Observed (ERA-Interim Re-Analyses) Tropical Cyclones (TCs) composite effect over West-North Pacific (WNP) ocean

2. How CMCC climate model represent Tropical Cyclones (TCs)

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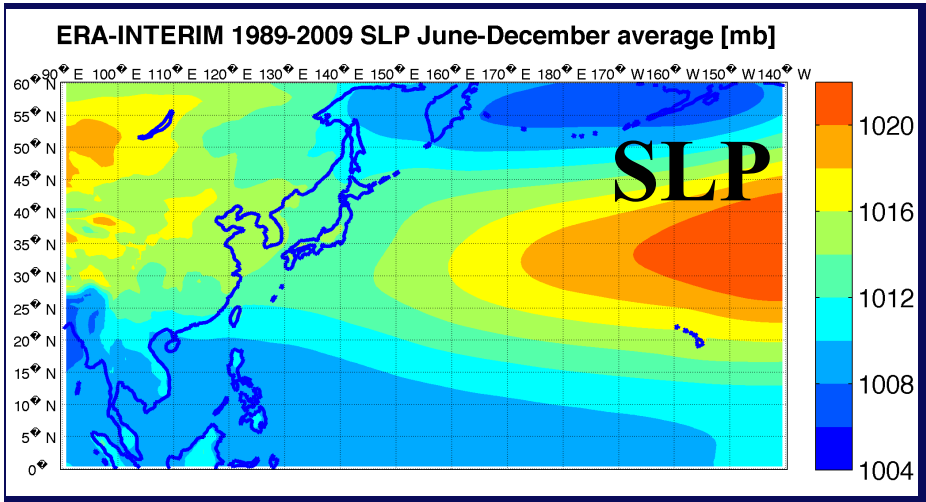
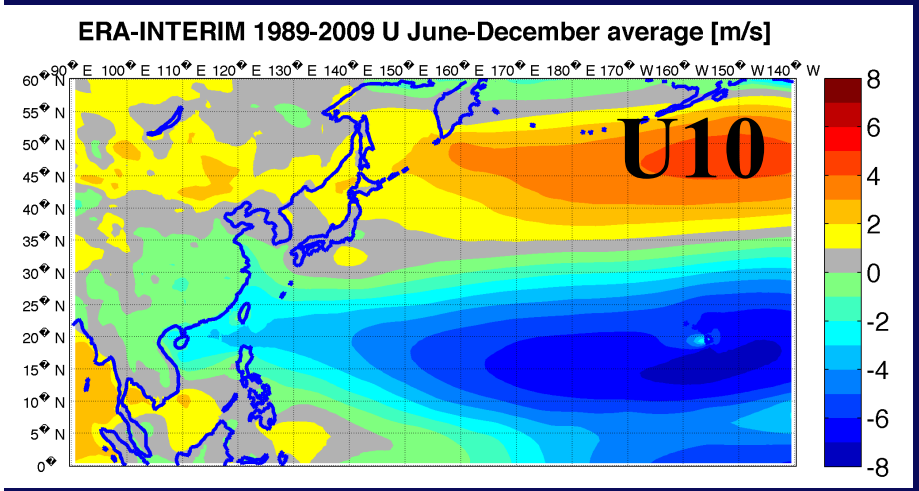


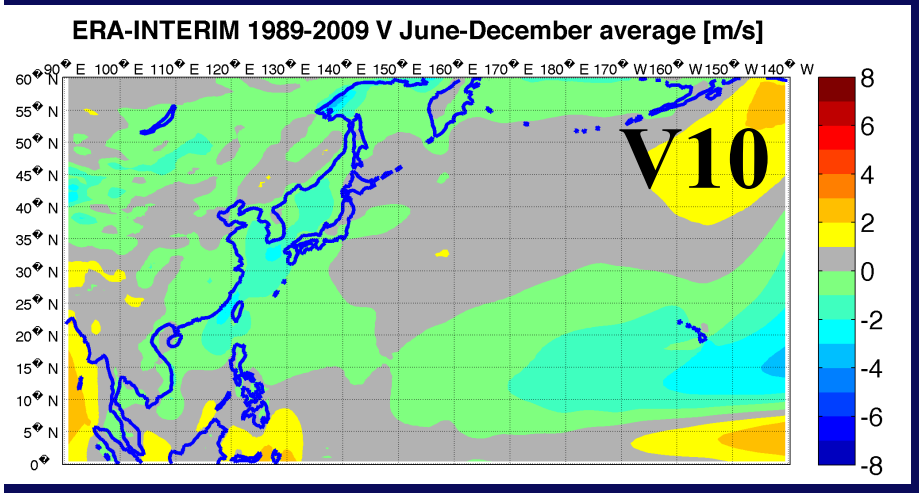
SLP

1989-2009 June-December
ERA-Interim CLIMATOLOGY

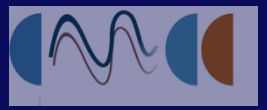


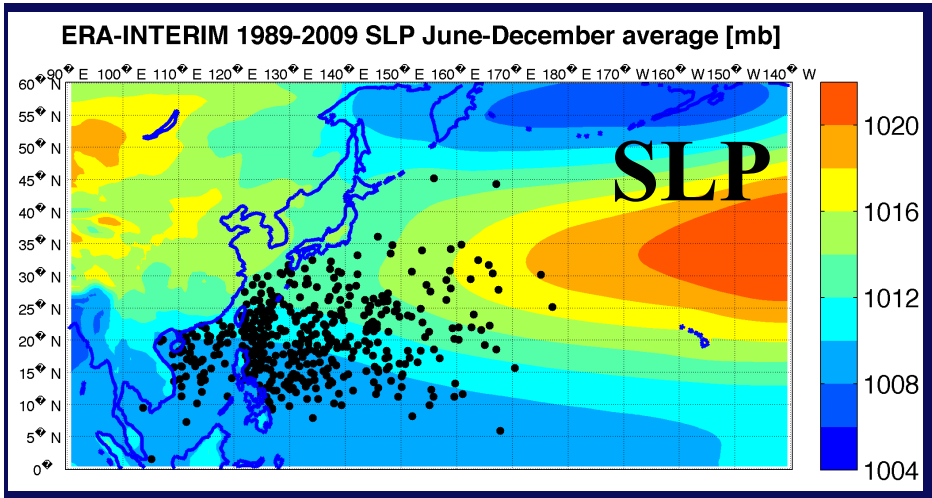
U10

West-North Pacific
(WNP)



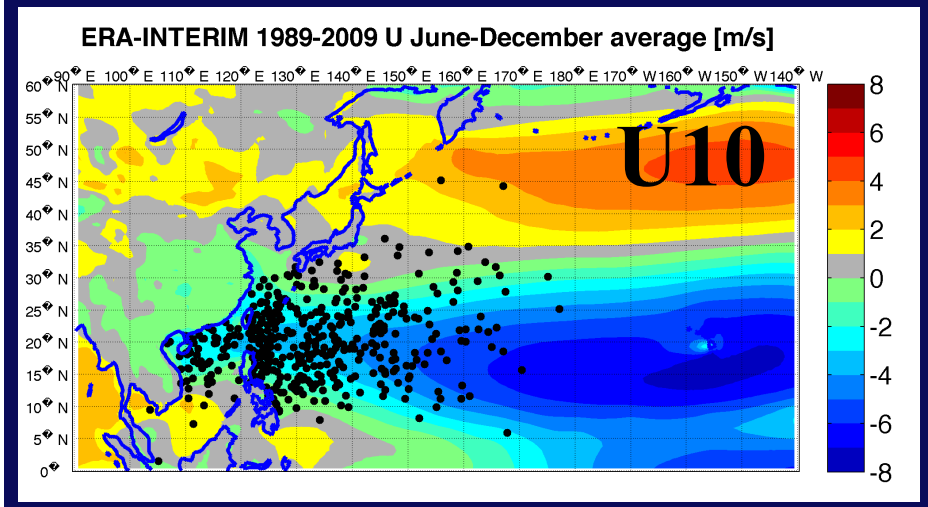
V10





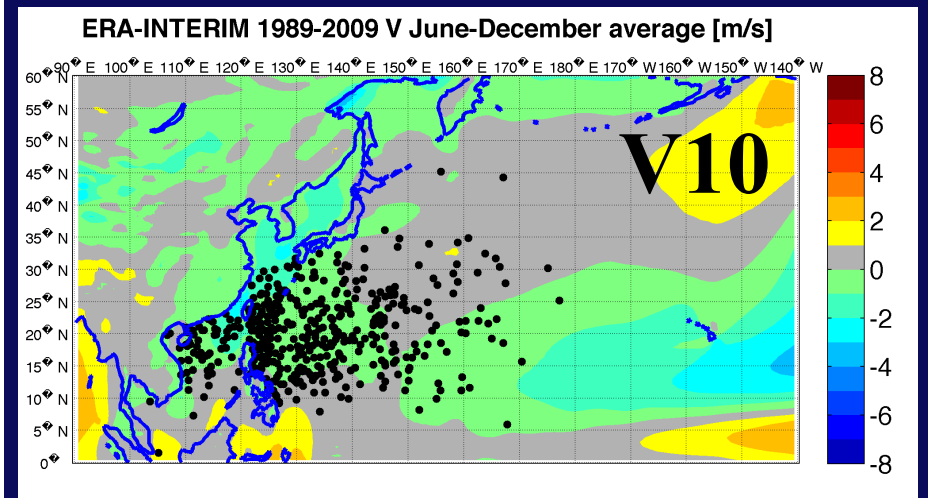
SLP

1989-2009 June-December
ERA-Interim CLIMATOLOGY
+
TYPHOONs max intensity location
(black dots:308 TY considered
->18Ty/year [Chan & Shi 1996])



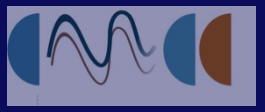
U10

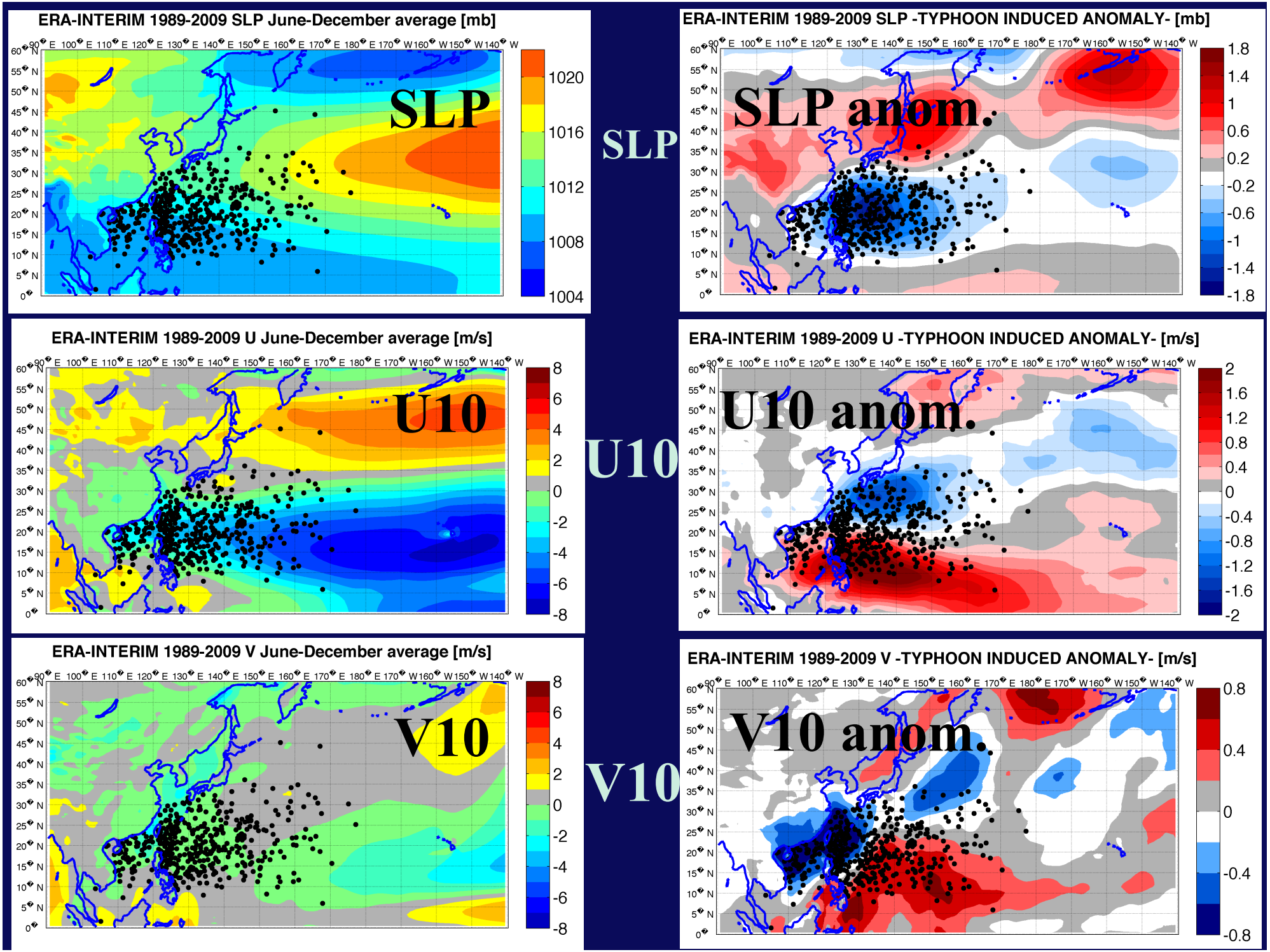
West-North Pacific
(WNP)



V10

Composite TC induced anomalies
computation on a daily time basis
Ongoing -> next slide




ERA-INTERIM 1989-2009 SLP June-December average [mb]
SLP
1020
1016
1012
1008
1004
ERA-INTERIM 1989-2009 SLP -TYPHOON INDUCED ANOMALY- [mb]
SLP anom.
1.8
1.4
1
0.6
0.2
-0.2
-0.6
-1
-1.4
-1.8
SLP
ERA-INTERIM 1989-2009 U June-December average [m/s]
U10
8
6
4
2
0
-2
-4
-6
-8
ERA-INTERIM 1989-2009 U -TYPHOON INDUCED ANOMALY- [m/s]
U10 anom.
2
1.6
1.2
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0.4
0
-0.4
-0.8
-1.2
-1.6
-2
U10
ERA-INTERIM 1989-2009 V June-December average [m/s]
V10
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ERA-INTERIM 1989-2009 V -TYPHOON INDUCED ANOMALY- [m/s]
V10 anom.
0.8
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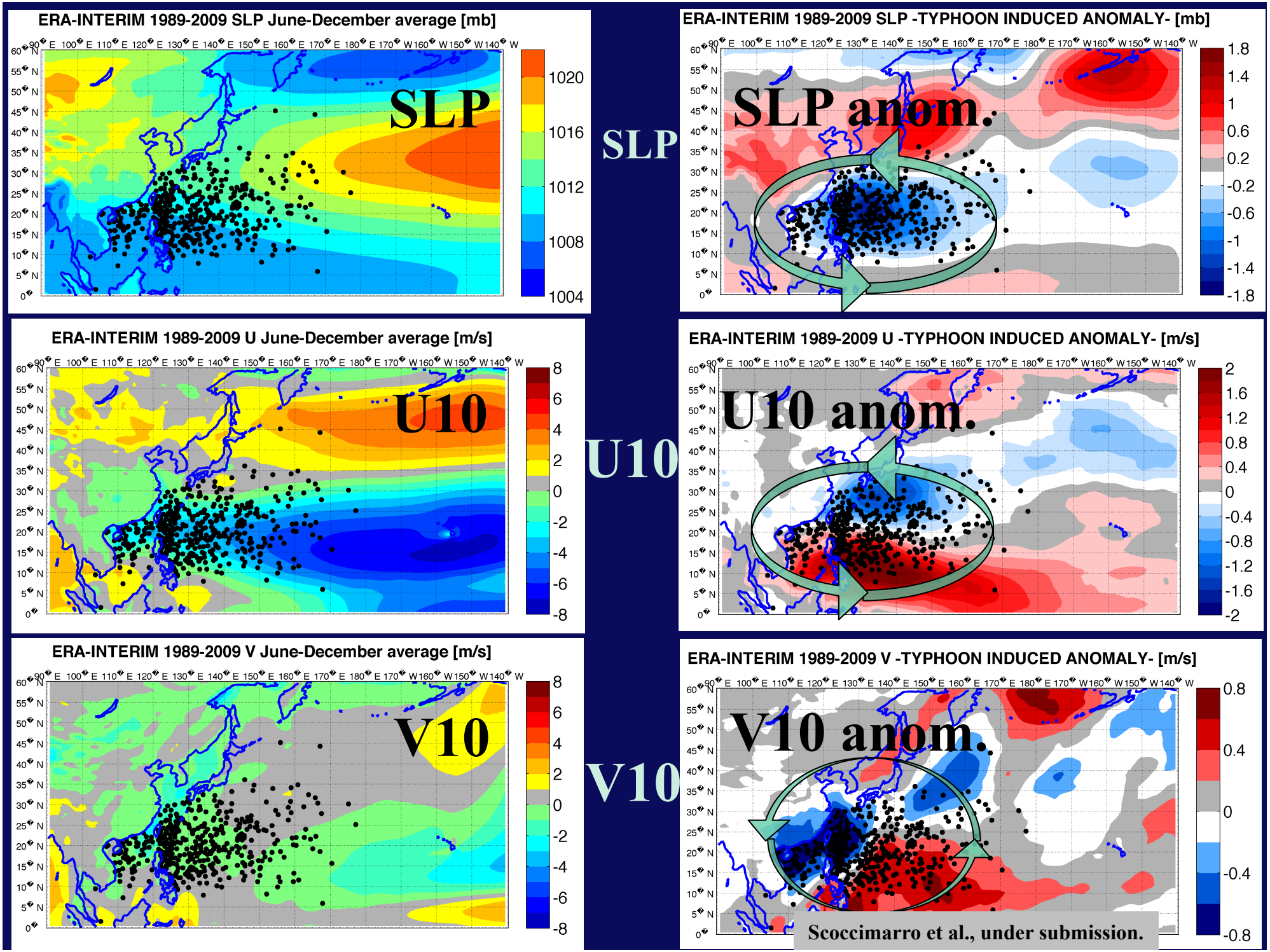
-0.4
-0.8
V10


ERA-INTERIM 1989-2009 SLP June-December average [mb]
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ERA-INTERIM 1989-2009 SLP -TYPHOON INDUCED ANOMALY- [mb]
SLP anom.
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ERA-INTERIM 1989-2009 U June-December average [m/s]
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ERA-INTERIM 1989-2009 V June-December average [m/s]
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ERA-INTERIM 1989-2009 V -TYPHOON INDUCED ANOMALY- [m/s]
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0.4
0
-0.4
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V10
Scoccimarro et al., under submission.

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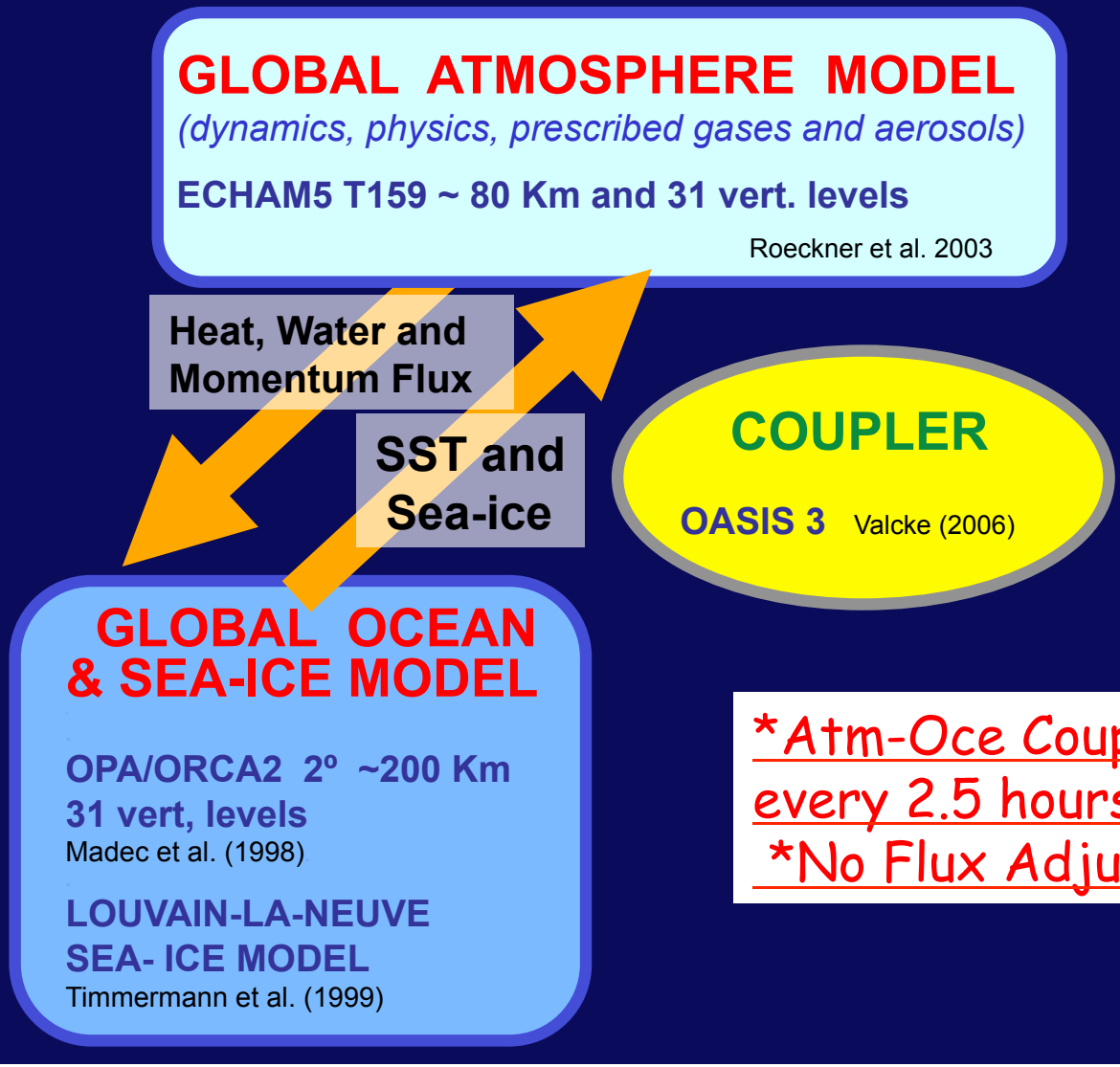
TCC interplay with the ocean: results from a fully coupled hi-res "Hurricane Resolving" High-Resolution Coupled General Circulation Model

(CMCC_MED evolution of INGV-SXG [Gualdi et al., *JoC* 2008])

This model is now running CMCC CMIP5 IPCC scenario exps

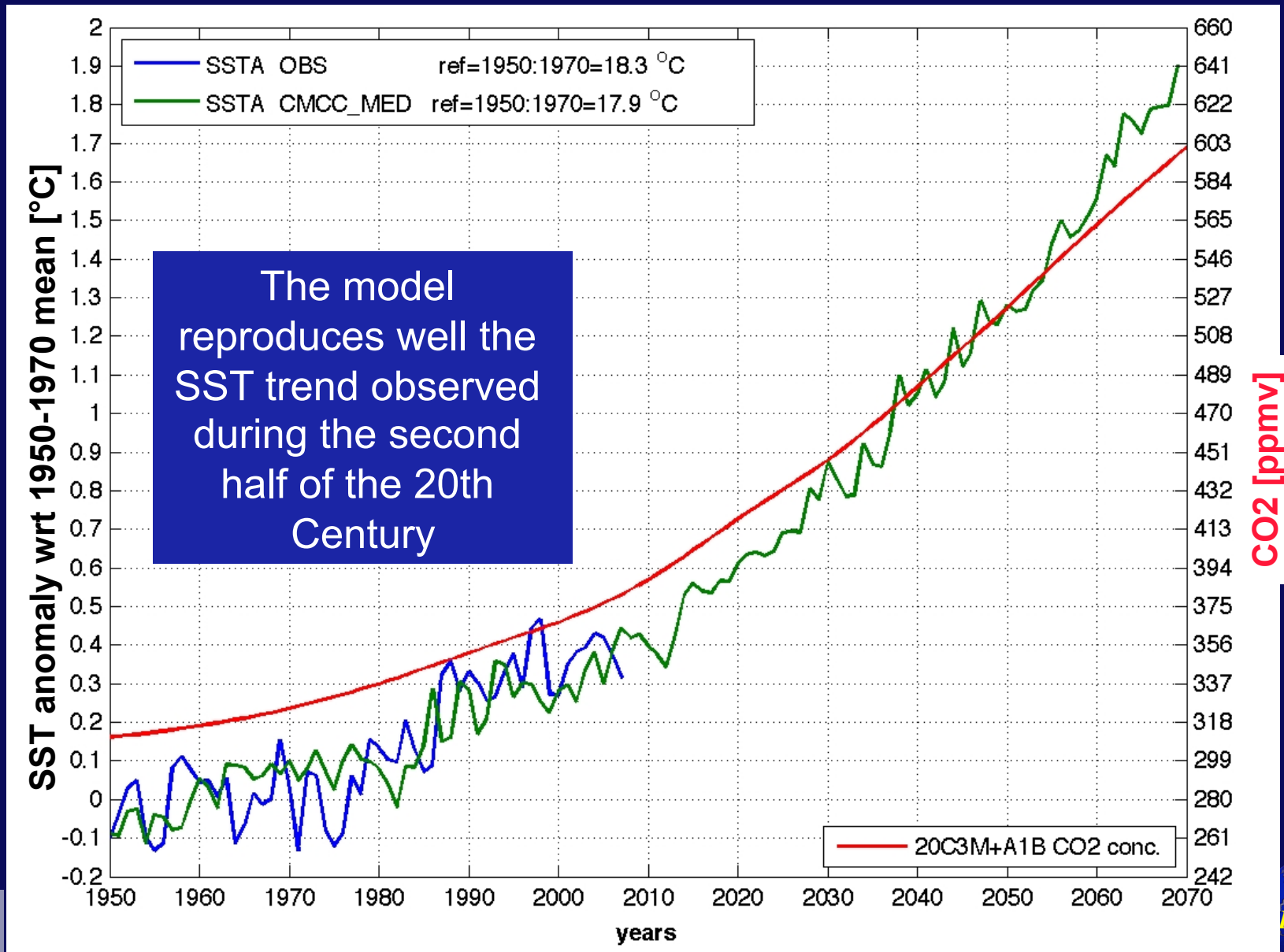


*Atm-Oce Coupling every 2.5 hours

*No Flux Adjustment

The CMCC climate simulation : 20C3M and A1B scenario

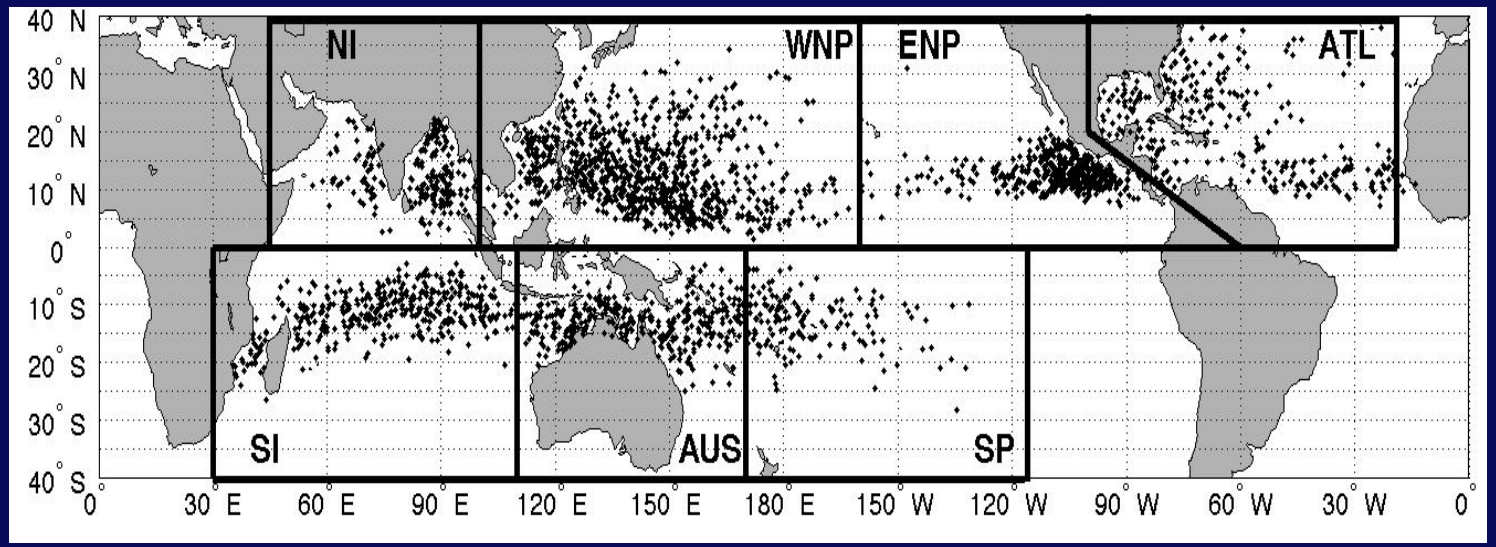
Evolution of the global mean SST Anomaly from 1950 to 2069: observation vs. model



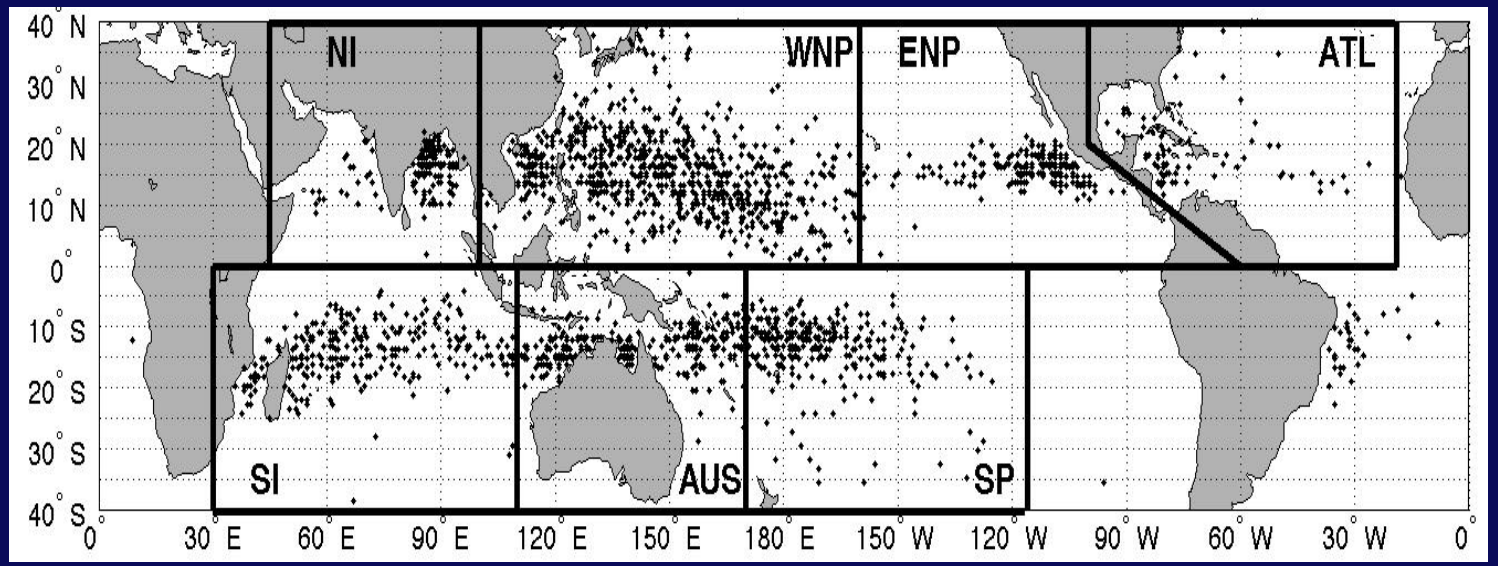
How the model represent Tropical Cyclones

TCs track starting points during 1970:1999

OBS



MODEL



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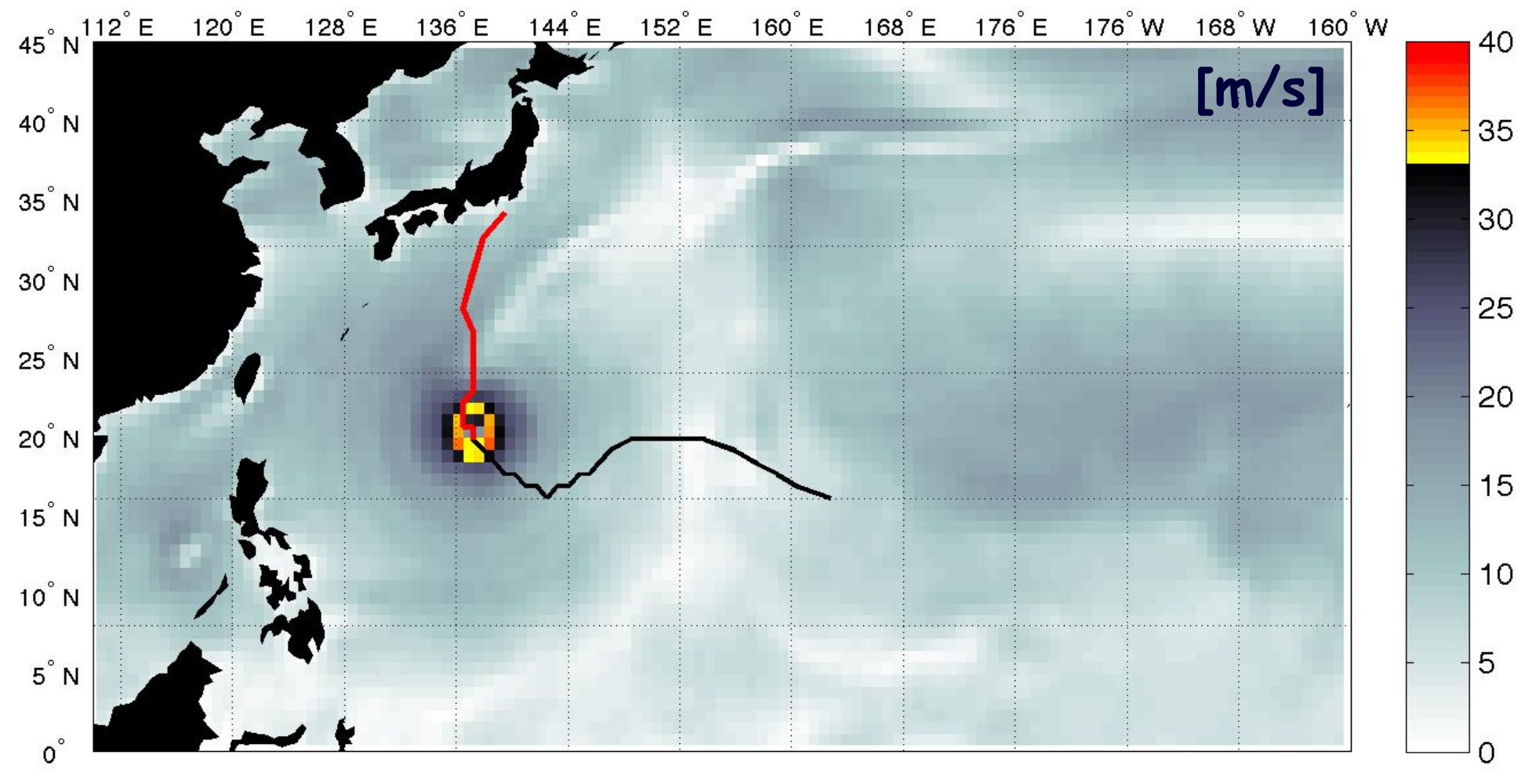
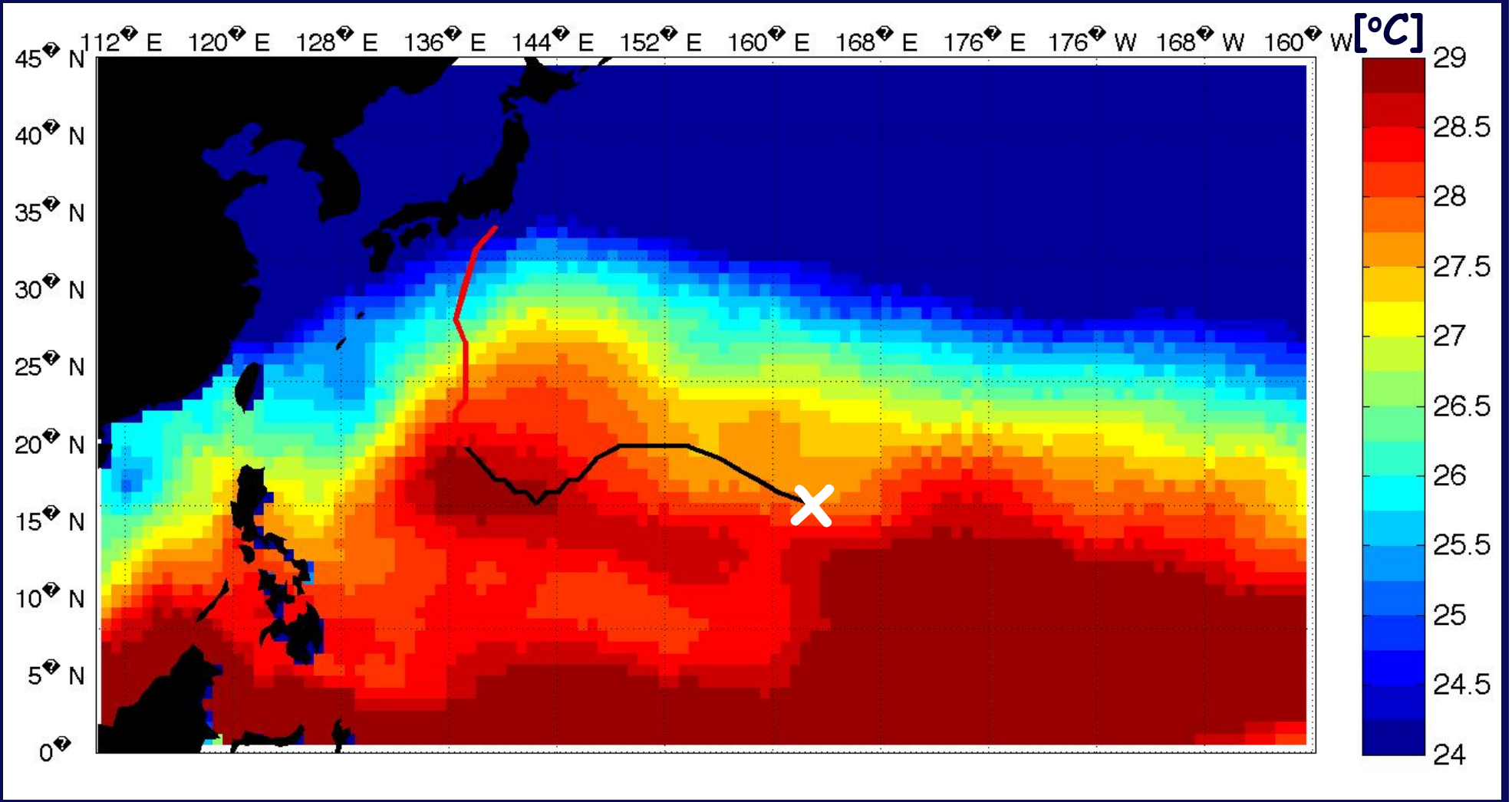
Modelled TC interaction with the ocean

10 meter max wind speed associated to a simulated cat1 typhoon



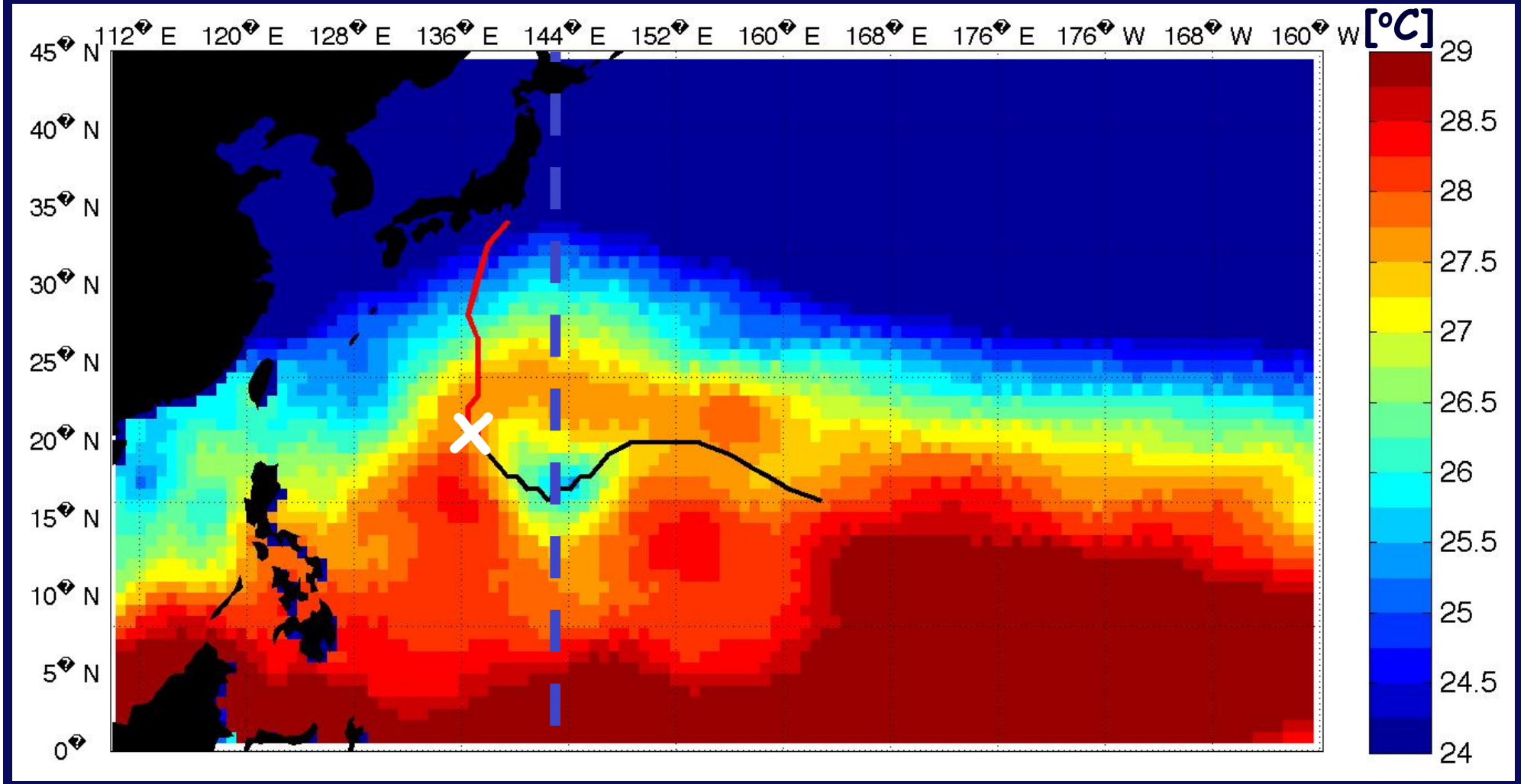
Modelled TC interaction with the ocean

SST associated to a simulated cat1 typhoon: before



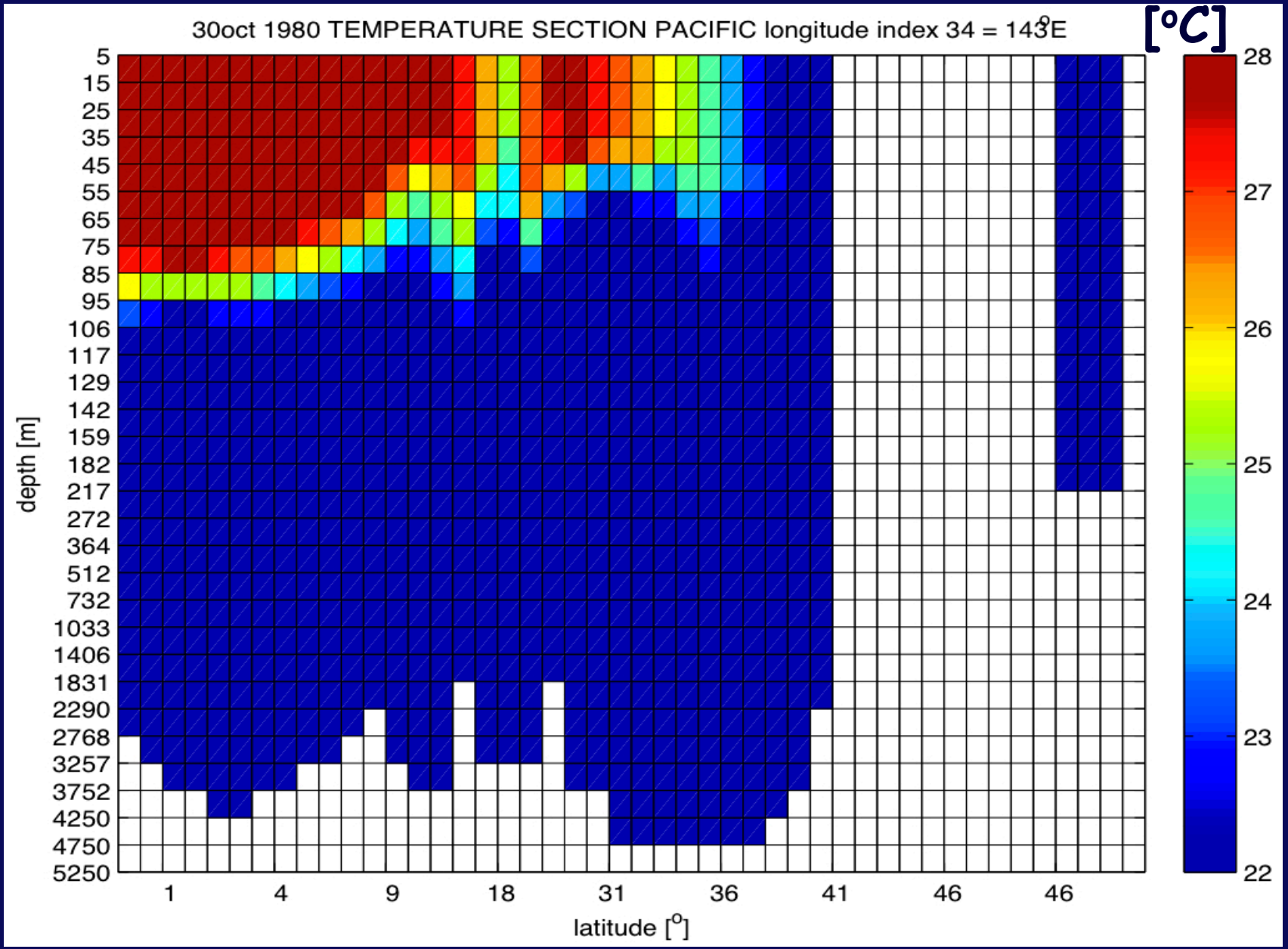
Modelled TC interaction with the ocean

SST associated to a simulated cat1 typhoon: after



Modelled TC interaction with the ocean

Sea Surface Cooling induced by a simulated cat1 typhoon

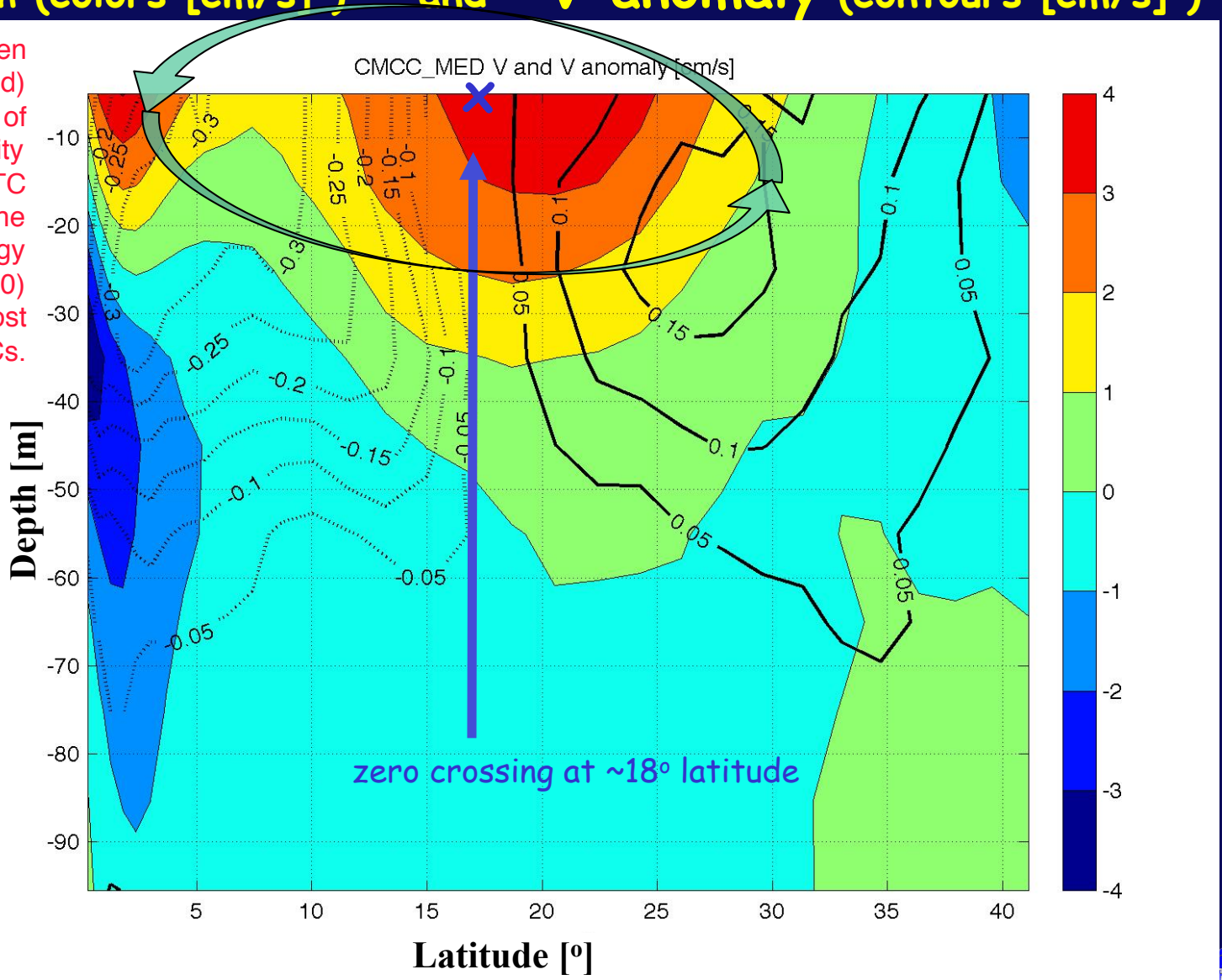


the TCC fingerprint on the ocean

Meridional Velocity anomaly induced by TCs:

V jun-dec mean (colors [cm/s]) and V anomaly (contours [cm/s])

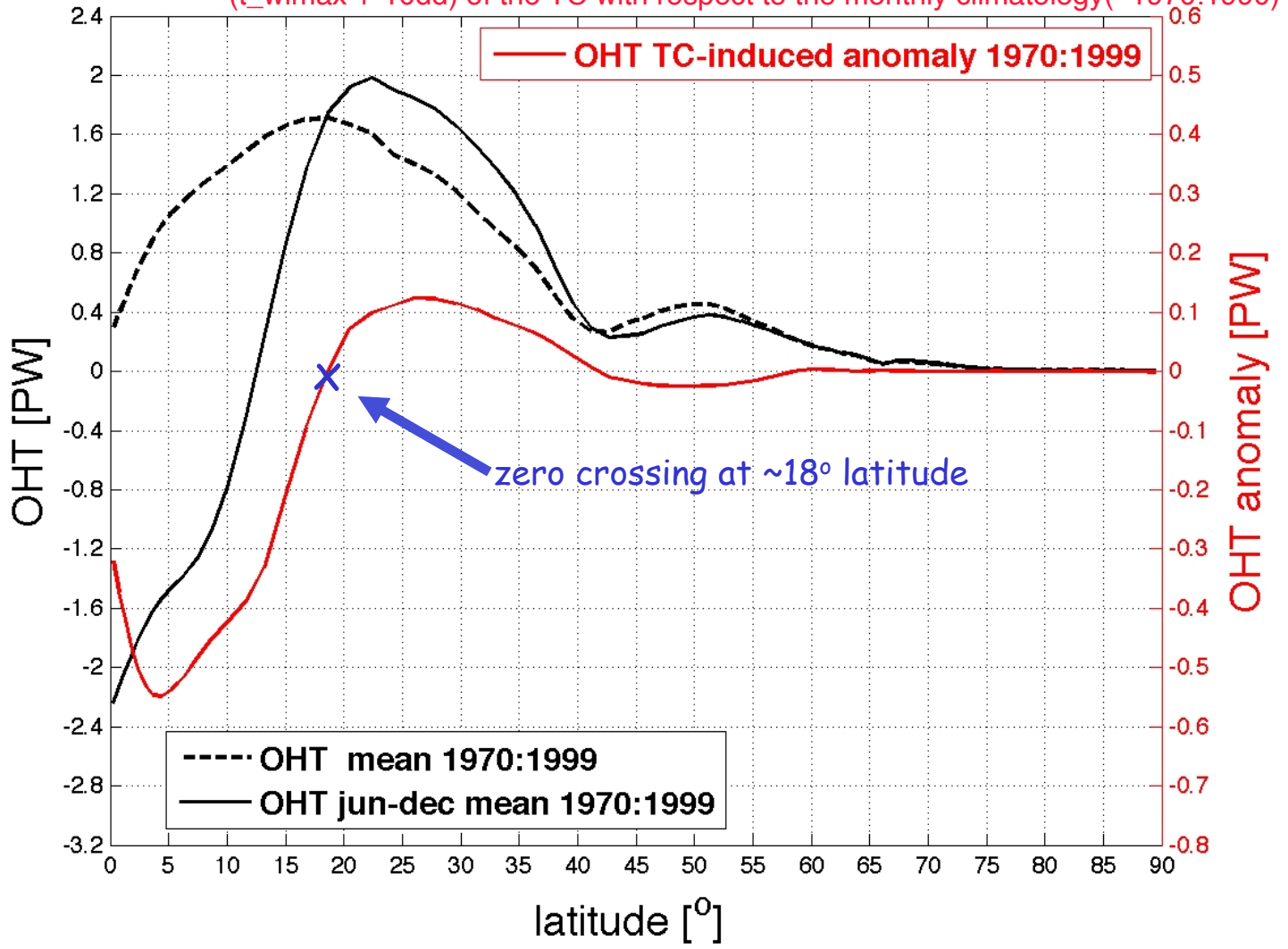
The anomalies have been computed (and averaged) for 20 days around the day of maximum intensity (t_wimax +-10dd) of the TC with respect to the monthly climatology (1970:1990) over the 100 most Intense TCs.



How TCCs affect the Ocean Heat Transport

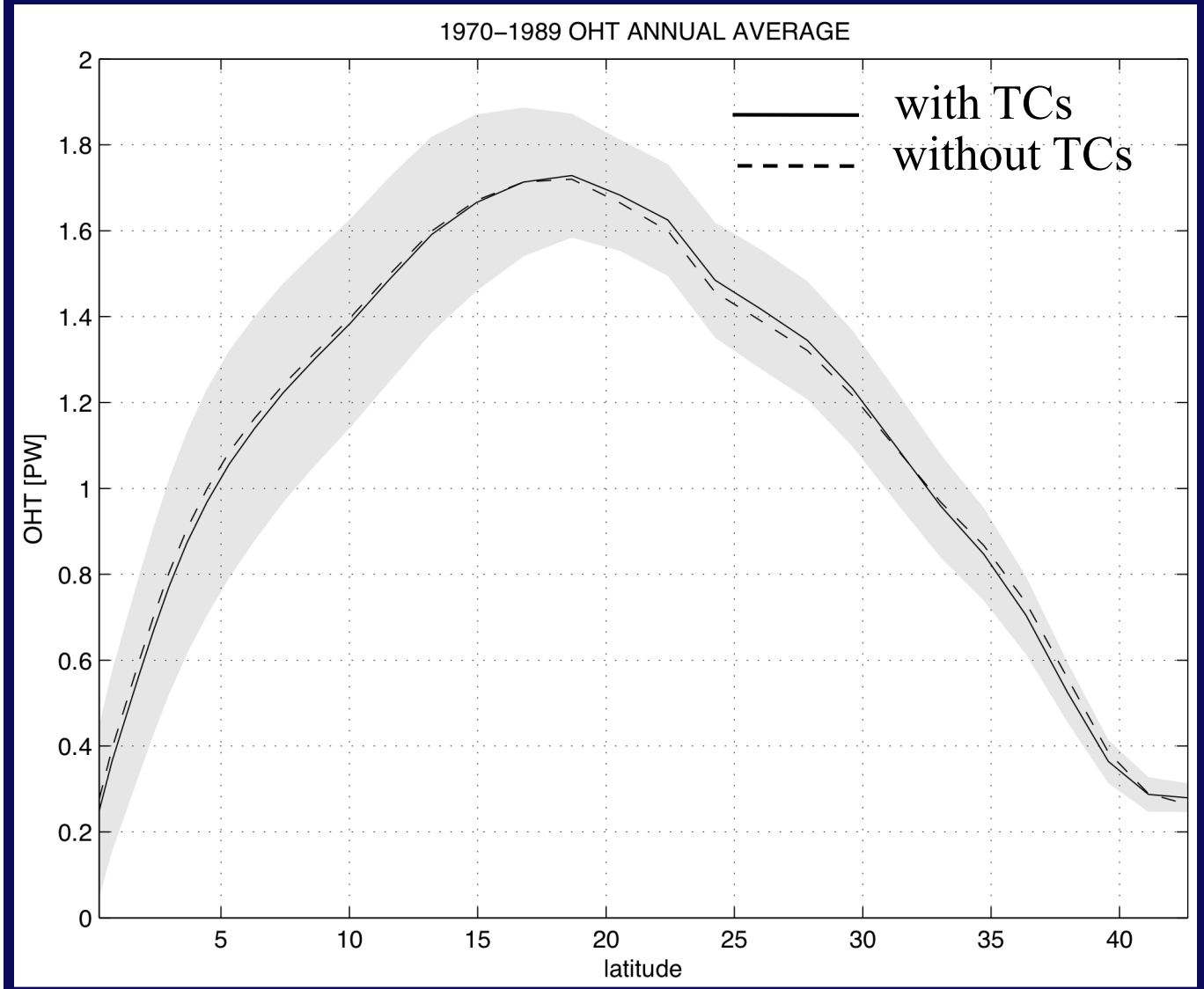
OHT as simulated by the model and TC induced OHT (TCiOHT) Anomaly

The anomalies have been computed (and averaged) for 20 days around the day of maximum intensity (t_wimax +-10dd) of the TC with respect to the monthly climatology(1970:1990)



TCs activity under the 21st century (A1B scenario)

OHT with and without TCs



The modelled heat anomalies below the mixed layer, induced by TCs on weekly time scales, do not propagate in the climatology:

Does it depend on the still too low modelled TC intensity?

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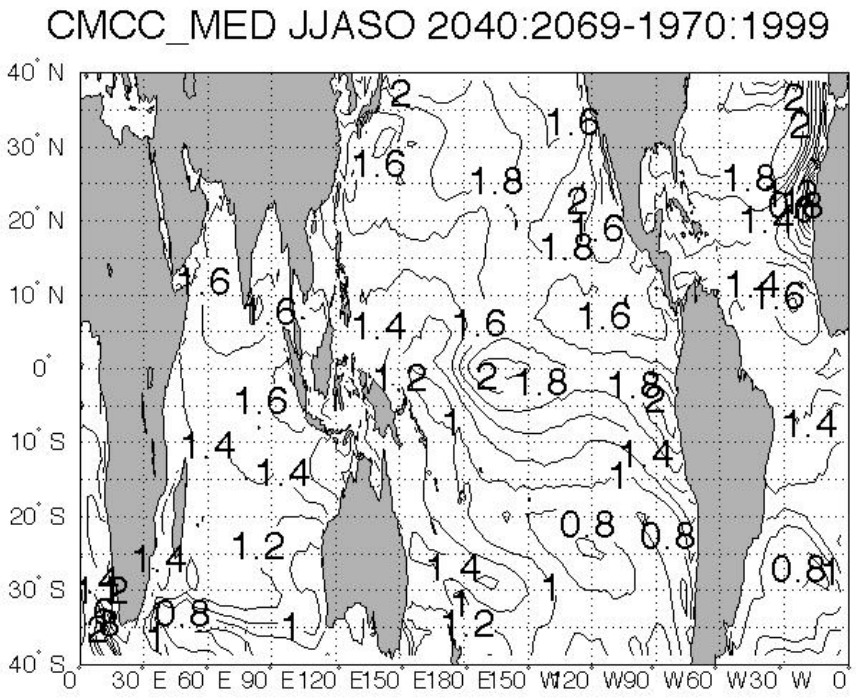
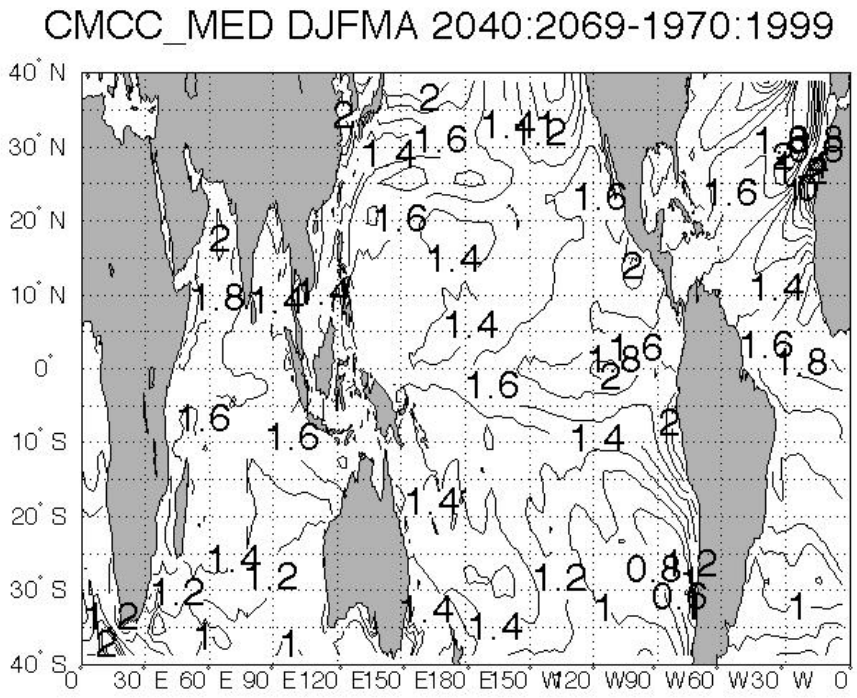
TCs activity under the 21st century (A1B scenario)

SST increase [°C] 2040:2069 - 1970:1999

JJASO

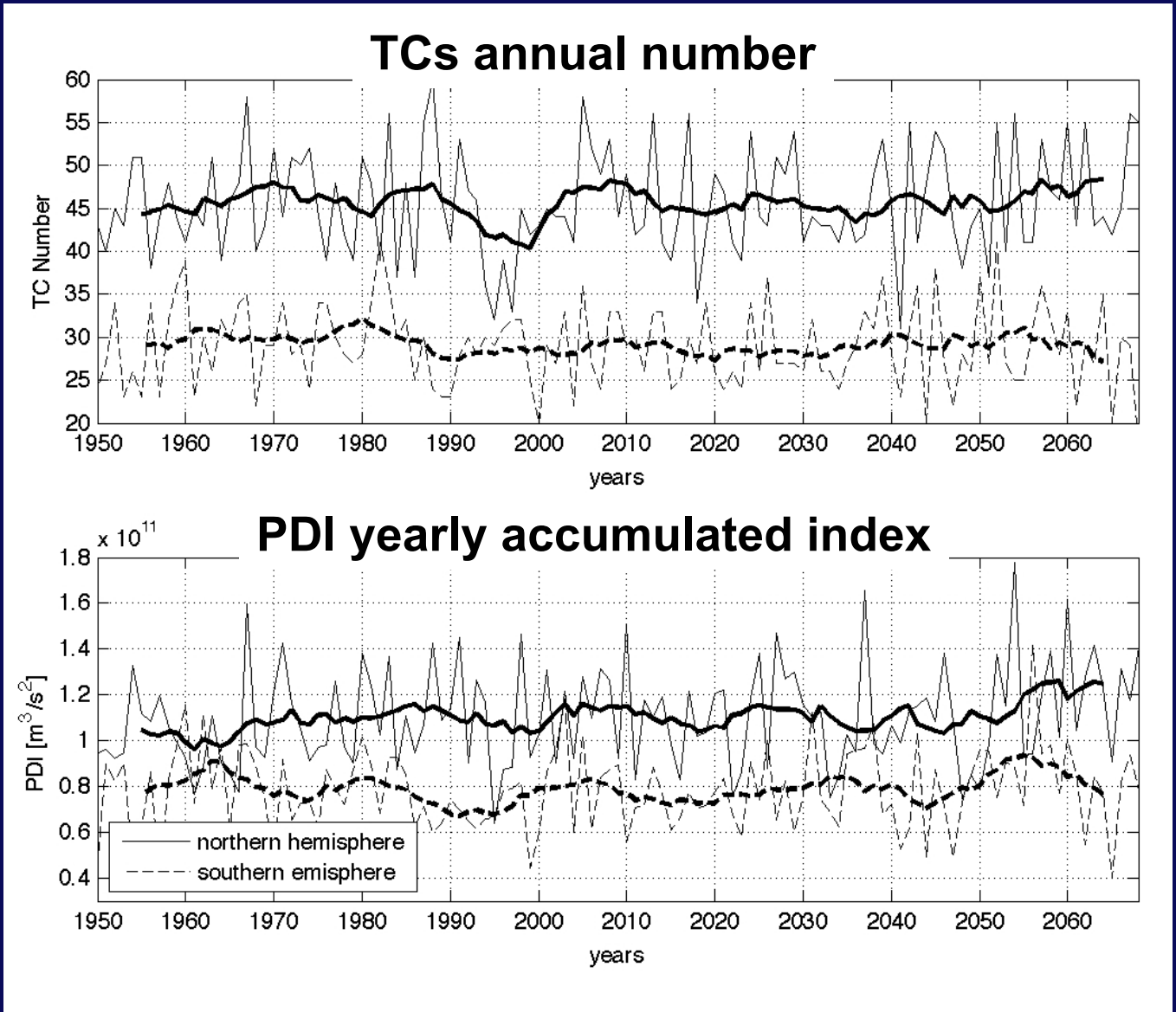


DJFMA



TCs activity under the 21st century (A1B scenario)

TCs number and Intensity (PDI)



Tropical Cyclones - Ocean feedbacks:
Effects on the Ocean Heat Transport as simulated by a
High Resolution Coupled General Circulation Model

CONCLUSIONS

A composite analysis for TC induced anomalies over ERA-Interim SLP, U10 and V10 fields, highlights wide cyclonic structures over the tropics, here defined as Tropical Composite Cyclones (TCCs).

TCCs act reinforcing trade winds at high tropical latitudes (20°-35°N) and weakening them at low latitudes (5°-20°N) as confirmed by CMCC model results.

The TCC induced overturning cells in the ocean velocity cause a Ocean Heat Transport (TCiOHT) anomaly:
The *Poleward* OHT *out of the tropics* increases (*) but also increases the OHT *into the deep tropics* (**) on weekly time scales without impact the yearly averaged large–scale meridional heat advection (***).

(*) [Emanuel, 2001] (**) [Jansen & Ferrari, 2009] (***) [Jansen 2010]

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Tropical Cyclones - Ocean feedbacks: Effects on the Ocean Heat Transport as simulated by a High Resolution Coupled General Circulation Model

REFERENCES:

- Scoccimarro E., S.Gualdi, A.Bellucci, A.Sanna, P.G. Fogli, E.Manzini, M.Vichi, P.Oddo, A.Navarra (2011) Effects of Tropical Cyclones on Ocean Heat Transport in a High Resolution Coupled General Circulation Model ***J. of Clim.* 2011 doi*: 10.1175/2011JCLI4104.1 in press (next week).***
Early online release: ***http://journals.ametsoc.org/doi/pdf/10.1175/2011JCLI4104.1***

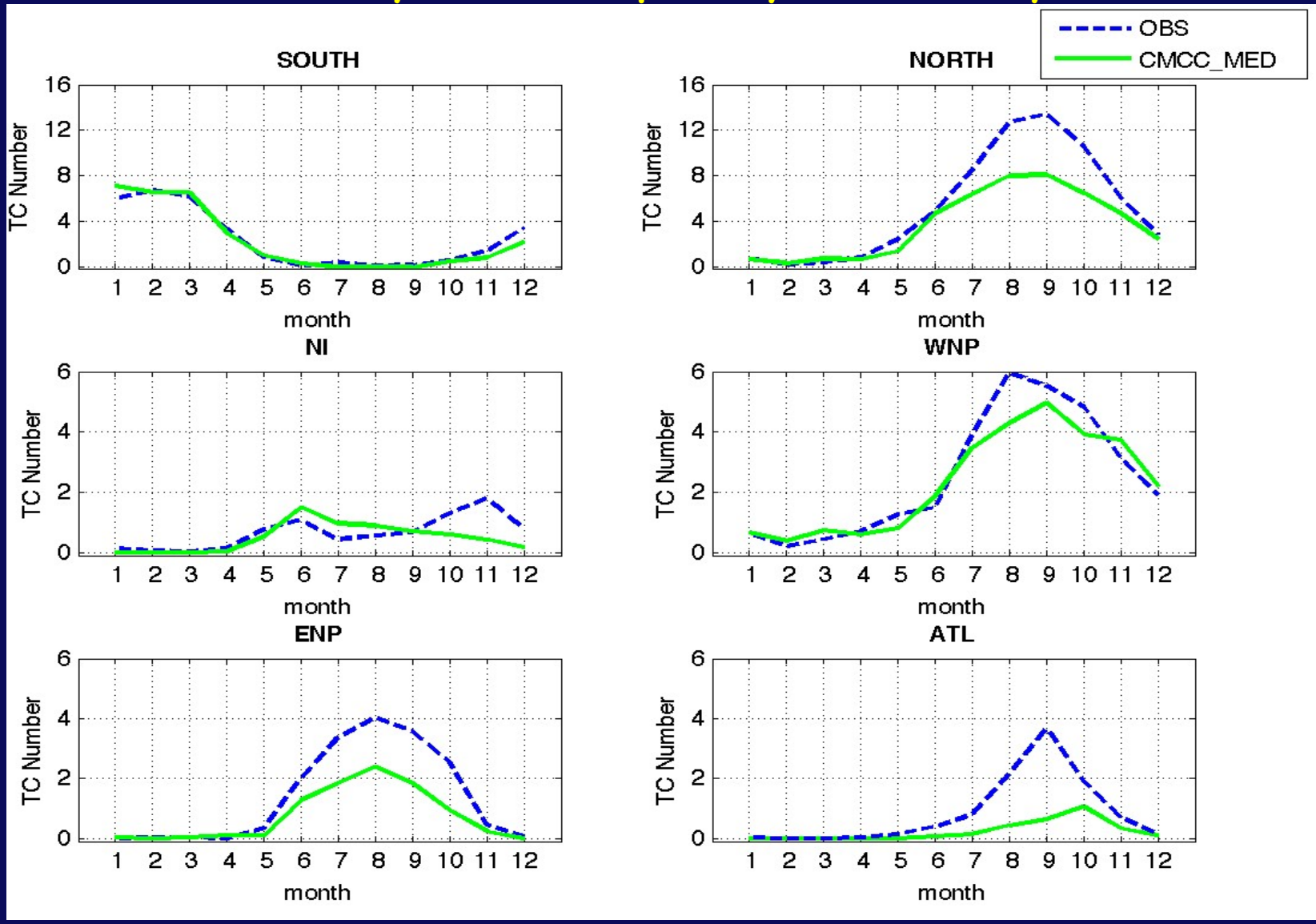
- Scoccimarro E., S. Gualdi, A. Navarra:
The Tropical Composite Cyclones: the integrated effect of hurricanes on the ocean-atmosphere coupled system. ***Under submission.***

scoccimarro@bo.ingv.it

Picture source: NOAA

How the model represent Tropical Cyclones

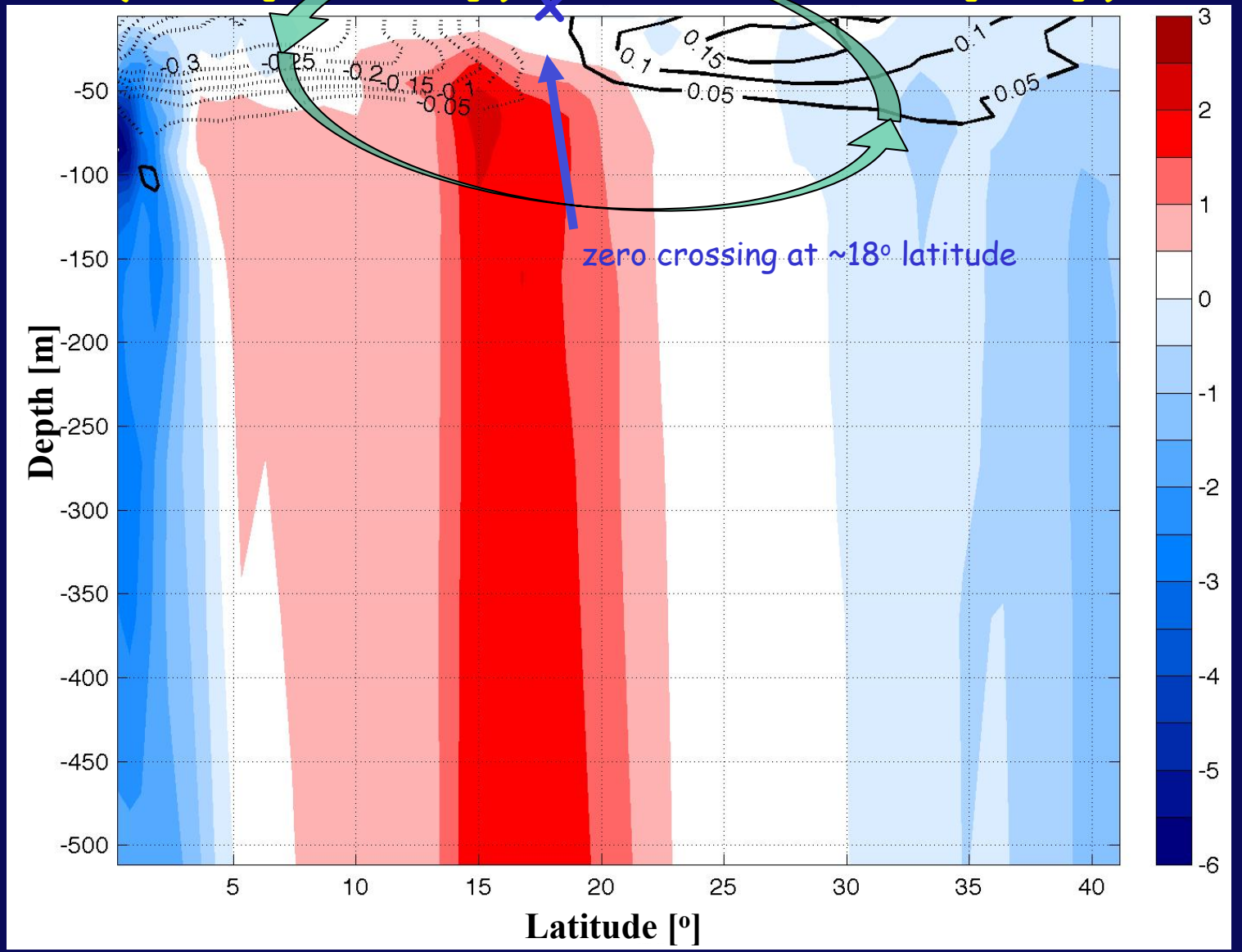
Seasonality of the Tropical Cyclone Activity



the TCC fingerprint on the ocean

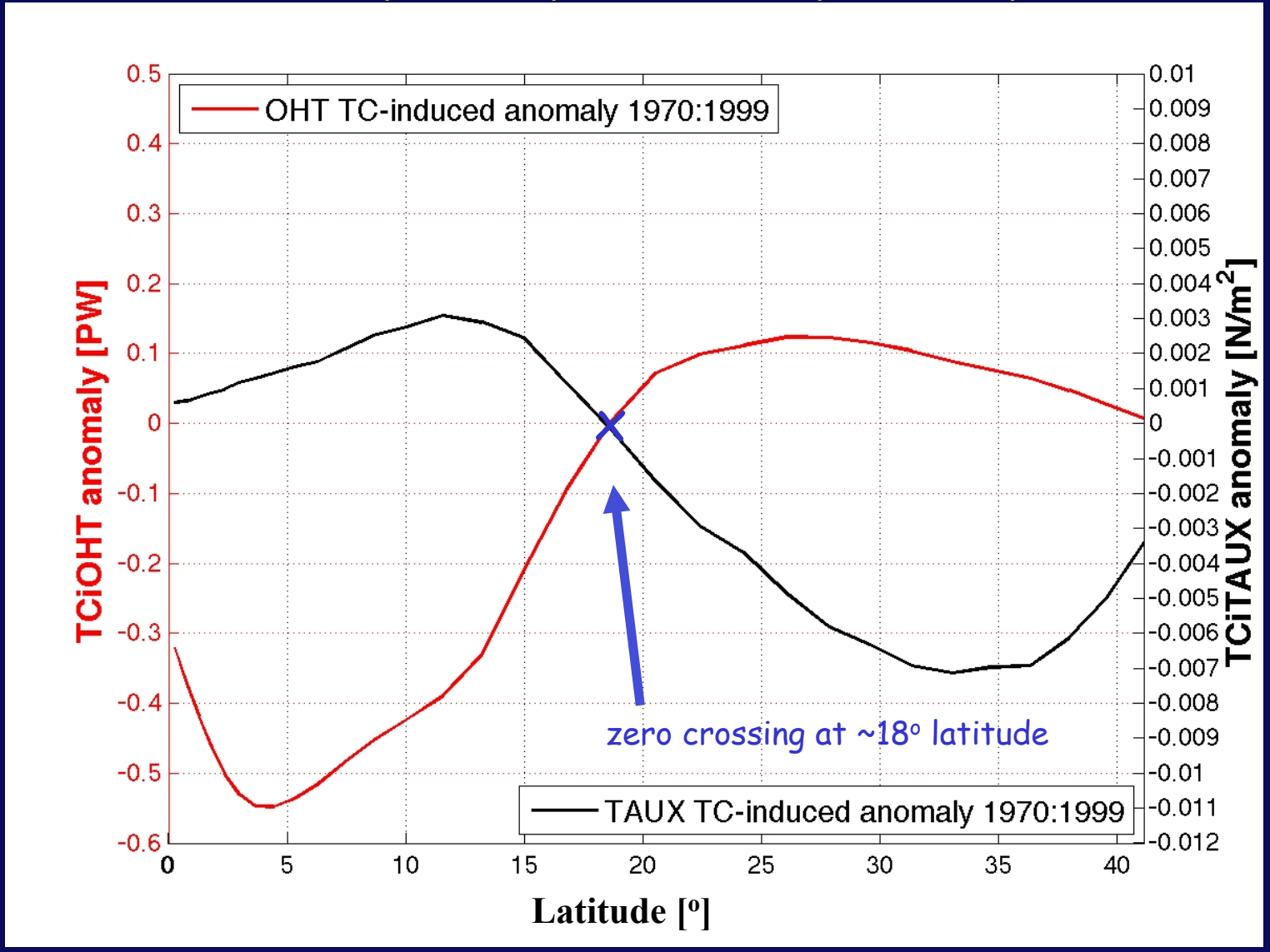
Ocean Velocity Anomalies induced by TCs:

W (colors [1e-5cm/s]) and V (contours [cm/s])



How TCCs affect the Ocean Heat Transport

TC induced OHT (TCiOHT) and TAUX (TCiTAUX) Anomalies



How the model represent Tropical Cyclones

TCs detection method

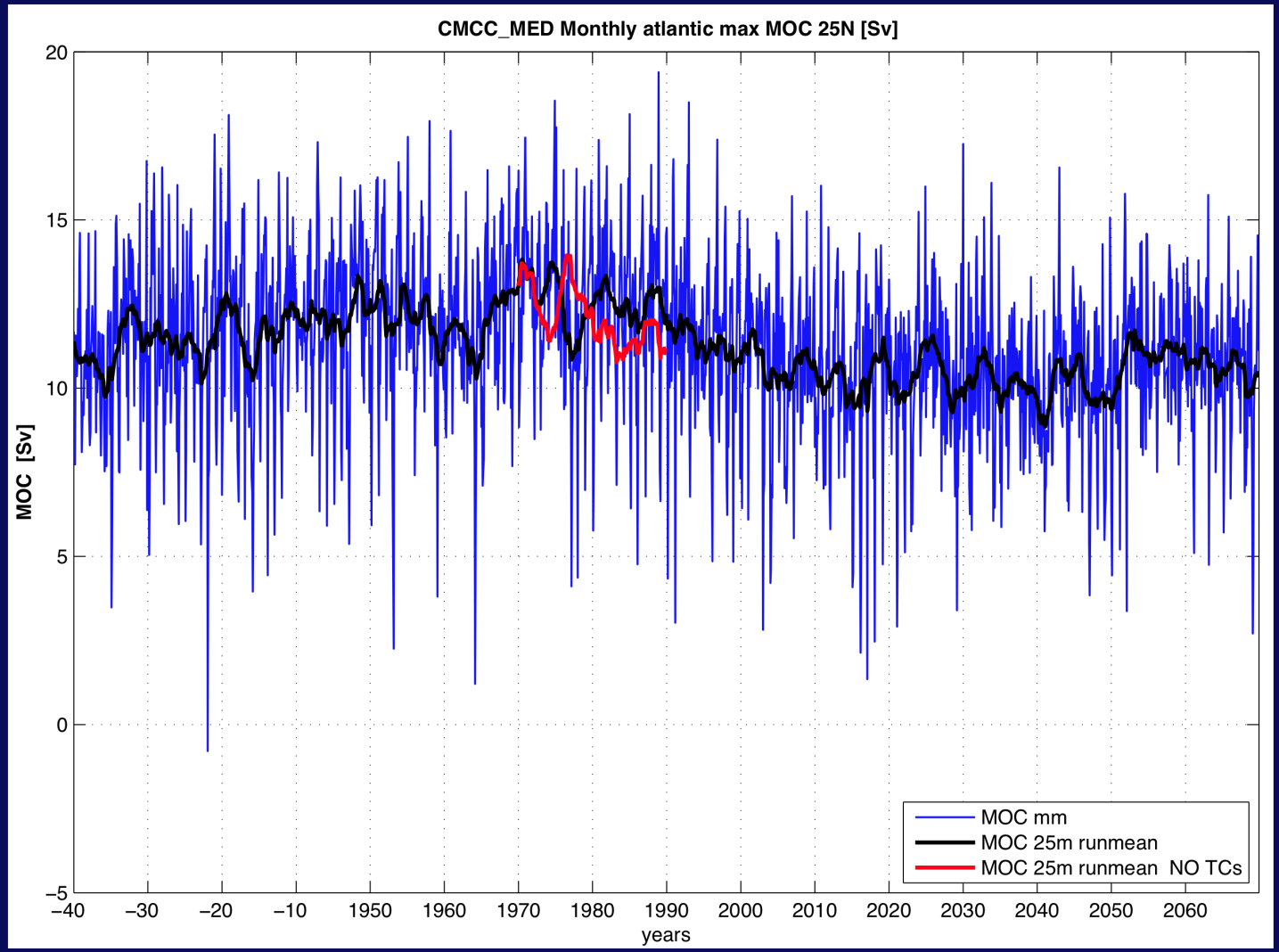
A model tropical cyclone is active over a grid point "A" if the following conditions are satisfied following the TC-MIP CSIRO method (*)

1. in A $\xi > 1 \cdot 10^{-5}$ s^{-1} at 850 hPa
2. relative minimum of SLP, and surface slp anomaly > 2hPa in an area of 350Km around A
3. in a 350Km A surrounding area the surf. wind velocity > 15.5 m/s (**)
4. wind velocity (850 hPa) > wind velocity (300 hPa)
5. Sum of T anomalies at 700, 500 and 300 hPa > 1°C
6. The above conditions must persist at least 24 hours

(*) [TC-MIP http://www.earthsci.unimelb.edu.au/~kwalsh/tcmip_index.html]
(**) [Walsh et al 2007]

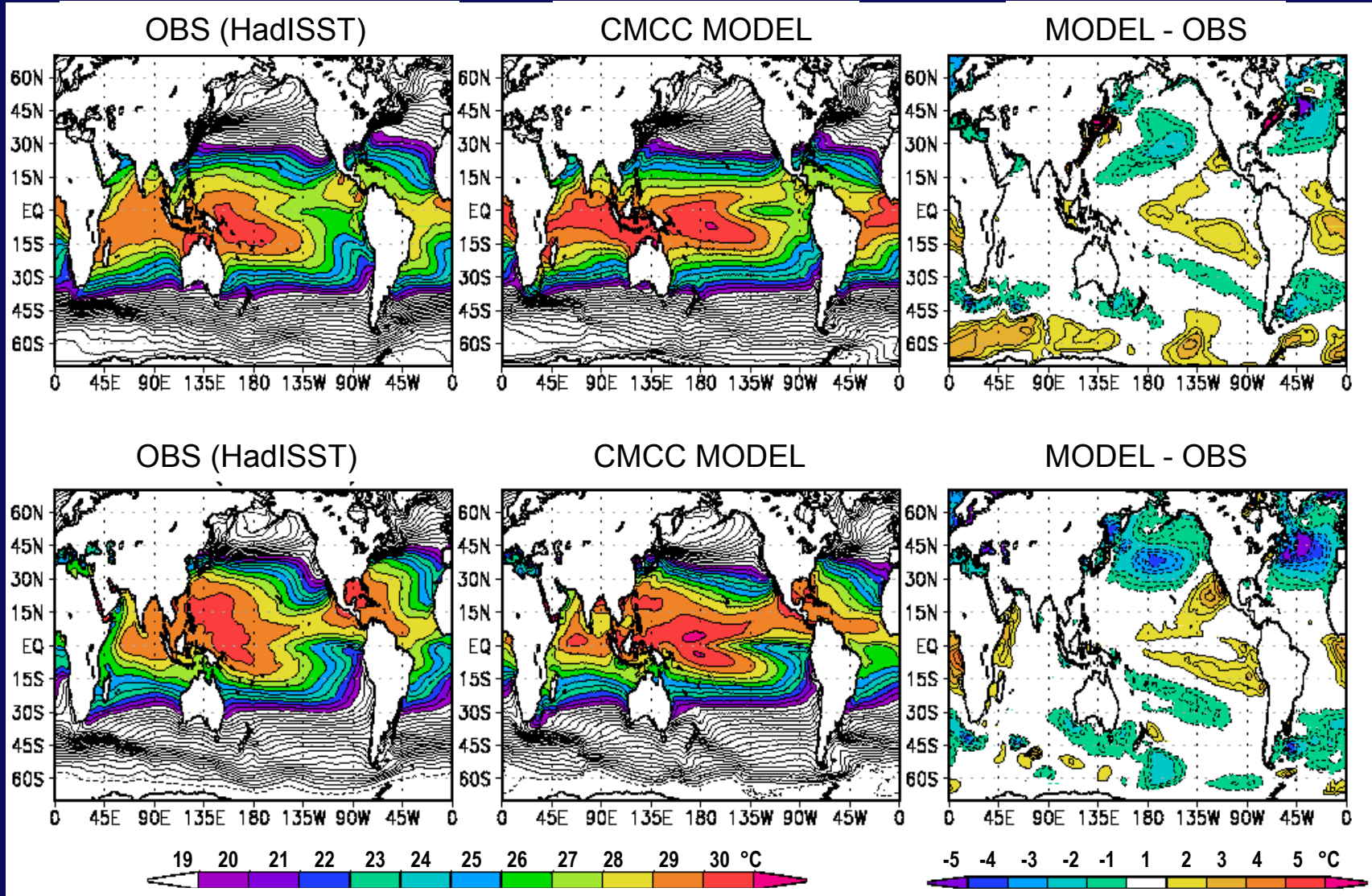
TCs activity under the 21st century (A1B scenario)

ATL 25N MOC



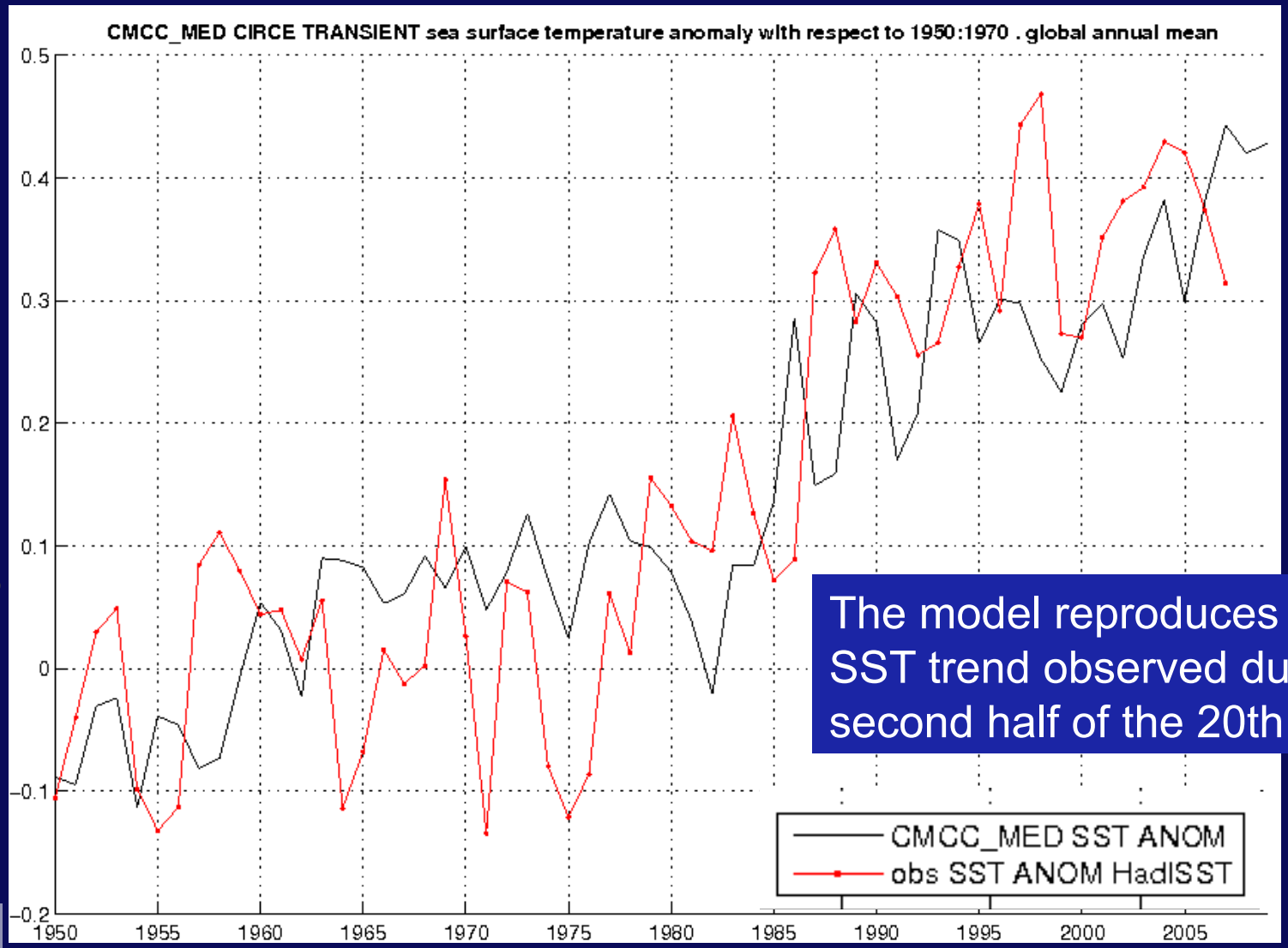
The CMCC climate simulation: present climate

Sea-Surface Temperature [°C] 1951-2000 mean



The CMCC climate simulations: reproduction of the observed climate

Evolution of the global mean SST from 1951 to 2000: observation vs. model



The model reproduces well the SST trend observed during the second half of the 20th Century

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Tropical Cyclones representation in ERA-Interim data set

The ERA-INTERIM (*) ECMWF Re-Analyses Data set

Data Assimilation through four-dimensional variational assimilation, 4D-Var, in a ~70 Km numerical weather prediction model (using a spectral grid with triangular truncation of 255 waves and a hybrid vertical coordinate system with 60 levels.).

Fields assimilated:
-Aircraft observations
-Ocean drifter observations
-Wind profiler observations
-Balloon-borne observations
-Dropsonde
-Satellite observations
-Surface observations

Covered period: 1989 – now
Data availability: 6 hourly

The sea-surface-temperature (SST) and sea-ice fields as used in ERA-Interim come from these sources:
- NOAA/NCEP 2D-Var weekly dataset (Reynolds et al., 2002) ;
-Jan 1989-Jun 2001NOAA/NCEP OISST V2 weekly dataset (Fiorino, 2004) ;
- Jul 2001-Dec 2001NOAA/-NCEP Real-Time Global (RTG) daily dataset (Gemmill, 2007) ;
- Jan 2002-Jan 2009Met Office Op. SST and Sea Ice Analysis (OSTIA) daily dataset (Stark et al., 2007) ;

(*) Simmons, A., S. Uppala, D. Dee, and S. Kobayashi, 2007: ERA-Interim: New ECMWF reanalysis products from 1989 onwards. Newsletter 110 - Winter 2006/07, ECMWF, 11pp.

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